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(56) Documents Cited

GB 2089061 A

EP 0575993 A2

EP 0307487 A1

EP 0220439 A2

EP 0194842 A2

US 5699464 A

US 4898450 A

US 4893890 A

(58) Field of Search

UK CL (Edition S) G2J JGEAT JGEB

INT CL⁷ G02B

(54) Abstract Title

Optical fibre end with an increased mode size

(57) An optical fibre 1, 2 which can comprise a cladding 4 around a central core 3 has an end portion 5 formed to permit the optical mode size to increase beyond the limits of the core. A micro lens 6 may be formed on the end face of the fibre or fibres. The end portion of the fibre may be heat treated by a CO₂ laser to disperse the core dopant, or a core-free fibre section (10, Fig 5) may be spliced to the end of the cored optical fibre to achieve the same effect. A lensed block (20, Fig 6) may also be used. A 10² increase in the collimated region is obtainable by virtue of this technique and it is useful in telecommunications such as where a Faraday rotator is to be used as an optical isolator.

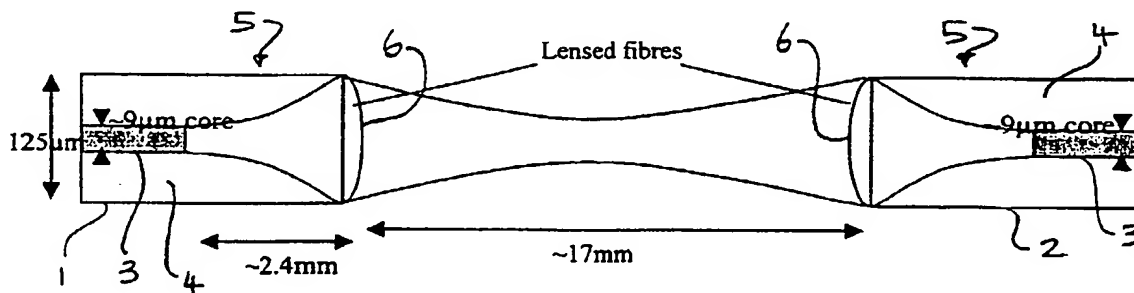


Figure 4 – Lensing expanded mode fibre – useful collimated region

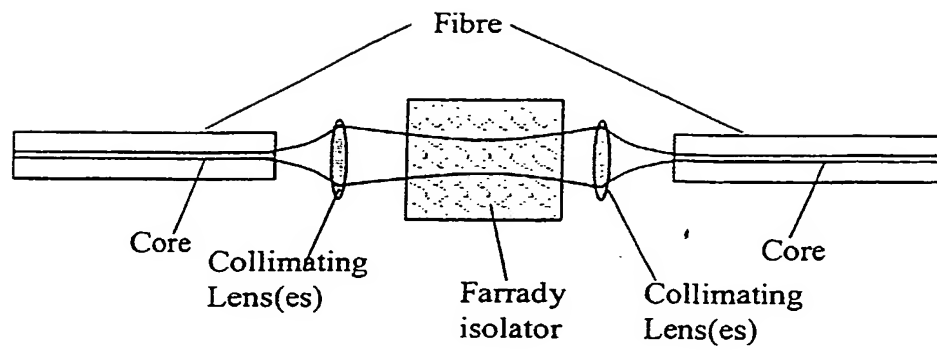


Figure 1 – Conventional Collimator

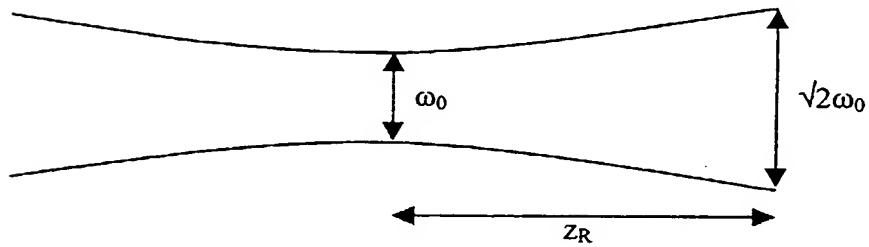


Figure 2 – Gaussian Beam Optics

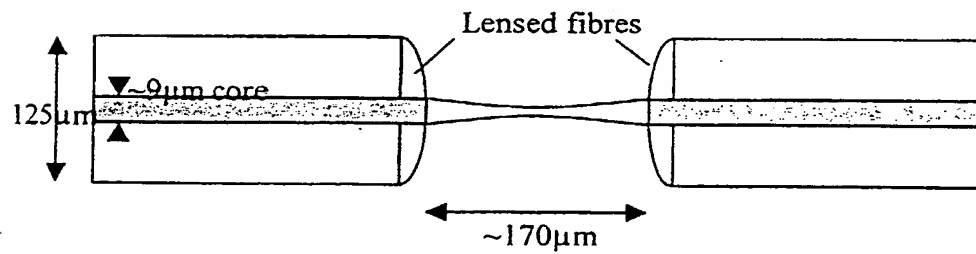


Figure 3 – Effect of Directly Lensing Single-mode fibre – unmanageably small collimated region

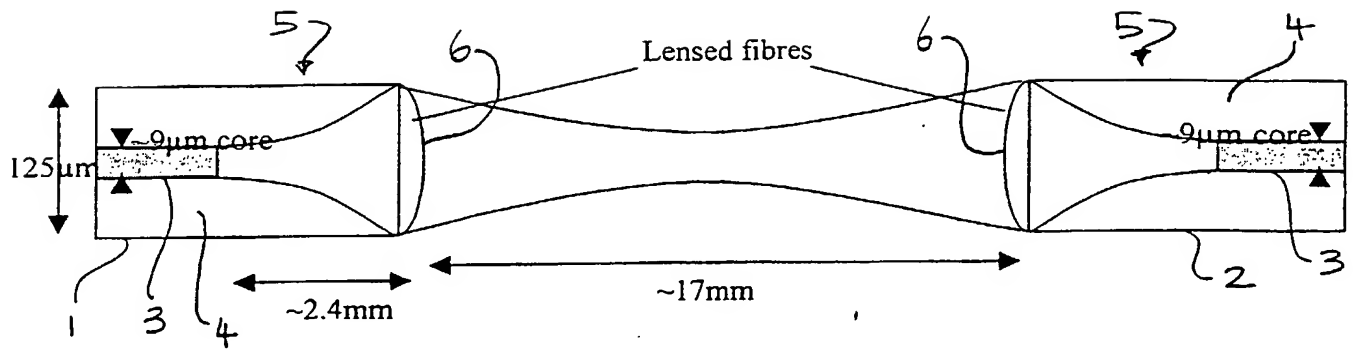


Figure 4 – Lensing expanded mode fibre – useful collimated region

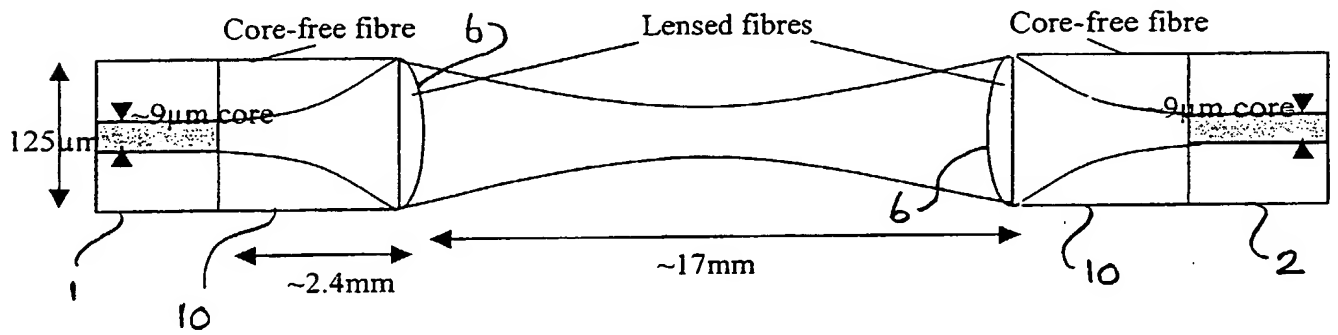


Figure 5 – Lensing core-free fibre ends

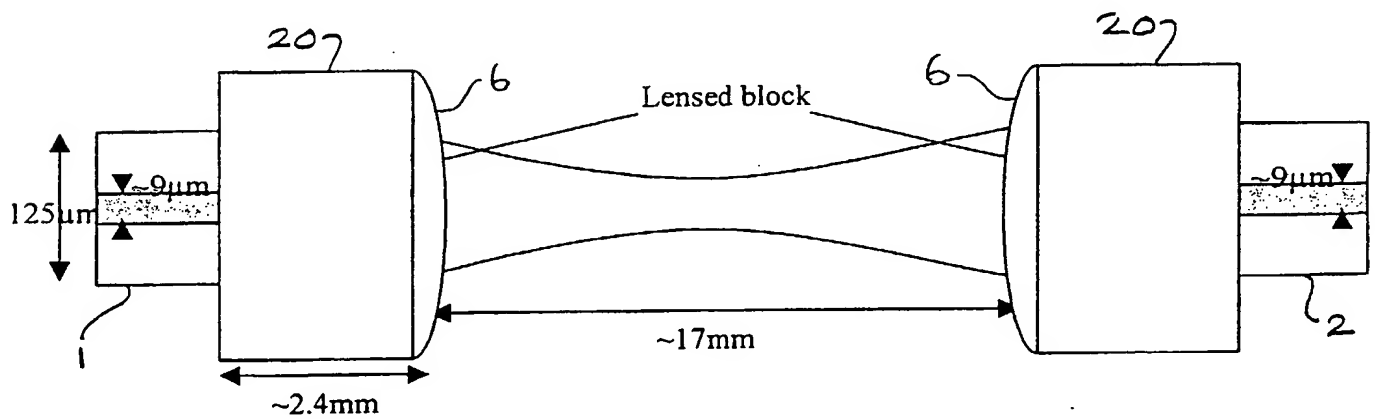


Figure 6 – Lensing encapsulated fibre ends

IMPROVEMENTS RELATING TO OPTICAL FIBRECOLLIMATORSField of the Invention:

5 This invention concerns improvements relating to optical fibre collimators for collimating a laser beam emerging from an optical fibre. The invention has particular, though not exclusive, application to the field of telecommunications.

10 Background of the Invention:

 There exist several applications where it is desired to collimate the laser beam emerging from an optical fibre, for example where a Faraday rotator is to be used as an optical isolator in telecommunications systems. Often, it is then required to couple the beam back into an optical fibre. This
15 task is generally achieved using free-space optics as shown in Figure 1 of the accompanying drawings. The collimating lenses shown in this figure may be either single or multiple element lenses.

 Such collimators are difficult to fabricate, partly due to the low F# of the lenses involved (and hence aberrations) but also due to the difficulty of
20 accurately aligning the elements of the lens and the fibre. The possibility of producing a lens form on the fibre end (eg as described in US-A-4 932 989) offers the opportunity to reduce the number of components involved, to directly produce superior aspheric lens forms and to increase the robustness

and reduce the physical size of the collimator. However, this approach has a fundamental flaw which is related to the size of the fibre core.

The range over which a Gaussian beam can be effectively collimated can be represented by the Rayleigh range, Z_R , which is the distance over which the beam increases in diameter from a waist ω_0 , to a diameter of $\sqrt{2}\omega_0$ as shown in Figure 2 of the accompanying drawings. For a lowest order Gaussian beam Z_R is equal to $\pi\omega_0^2/\lambda$ where λ is the wavelength.

The collimated range therefore depends on the spot size. For example, if it is attempted to collimate the beam from a single-mode fibre using a lens formed on the end of the fibre, the spot size at the fibre must be the fibre mode-field-diameter (MFD) which is typically $9\mu\text{m}$. Setting this diameter as equal to $\sqrt{2}$ times the minimum diameter gives the geometry shown in Figure 3 of the accompanying drawings, where the collimated range is only about $170\mu\text{m}$ which is insufficient for most purposes.

In order to obtain a greater collimated range it is necessary to employ a larger diameter beam on the collimating lens surface. The conventional approach, Figure 1, achieves this through the natural expansion of the beam from the fibre end.

Objects and Summary of the Invention:

It is accordingly the object of the present invention to overcome or at least substantially reduce the abovementioned problem.

The present invention combines lensing of the fibre tip with one or more techniques which increase the beam size on the lensing element in order to produce an effective monolithic fibre collimator.

Hereinafter described are various embodiments of the invention in all
5 of which the laser beam is allowed to expand beyond the core region of the fibre just prior to the (effective) end of the fibre in such a way that the beam is of increased diameter at the focussing element. As shown in Figure 4 of the accompanying drawings, if the optical mode is allowed to fill the OD of the fibre ($\sim 125\mu\text{m}$ diameter), the collimated range can be increased to a useful
10 $\sim 17\text{mm}$.

In a first embodiment, the dopant which defines the core of the fibre is diffused from the end portion of the fibre. This can be accomplished using a suitably controlled and spatially defined heat source. A laser is one such heat source.

15 In a second embodiment, the mode expansion length is accomplished by splicing a short length of "core-free" fibre onto the end of the existing single mode fibre. The lens shape is produced on this core-free fibre. This can be done either before or after the splicing.

In a third embodiment, the end of the fibre is encapsulated in a
20 transparent optical material onto which the lens shape is machined, again either before or after the attachment.

It will be appreciated that the various steps of fibre modification to allow mode size increase, lens form manufacture and the combination of the

modified fibre and lens form can be carried out in any order to produce essentially the same result.

The above and further features of the present invention are set forth in the appended claims and will be well understood from consideration of the following description given with reference to the accompanying drawings.

Description of the Drawings:

Figure 1 shows a conventional optical fibre collimator;

Figure 2 illustrates Gaussian beam optics;

Figure 3 illustrates the effect of providing lenses on the ends of optical fibres as taught in the prior art;

Figure 4 illustrates a first embodiment of the invention;

Figure 5 illustrates a second embodiment of the invention; and

Figure 6 illustrates a third embodiment of the invention.

Detailed Description of the Embodiments:

Figures 1 to 3 illustrate the prior art and explain the problems which the present invention aims to solve, and Figure 4 to 6 illustrate exemplary embodiments of the present invention.

Referring to Figure 4, first and second optical fibres 1 and 2 are shown, each comprising a core 3 and a surrounding cladding 4, the core 3, as is well known, being defined by doping of the glass material of the optical fibre. As shown, each fibre 1 and 2 has an end portion 5 in which the core

dopant has been dispersed by diffusion as a result of heat treatment, for example by means of a laser such as a CO₂ laser. By virtue of the dispersion of the core dopant in the fibre end portions 5, a laser beam traversing the core of optical fibre 1 is permitted to expand before it exits the end face of the fibre where a collimating lens formation 6 is provided, for example by a laser micromachining process such as is described in US-A-4 932 989. Similarly, in the optical fibre 2 an end portion 5 is formed which has the reverse effect. For an optical fibre having an outer diameter (OD) of 125µm and a core diameter of about 9µm, a collimation range of the order of 17mm can be obtained as compared to the only 170µm collimation range of the prior art Figure 3 arrangement.

In the Figure 5 arrangement, a short length 10 of core-free optical fibre is spliced onto the ends of the optical fibres 1 and 2 and lenses 6 are formed on the facing ends of the two optical fibres so as to achieve substantially the same result as is obtained by the Figure 4 embodiment.

Figure 6 is yet another arrangement embodying the present invention in which the ends of the optical fibres 1 and 2 are encapsulated in transparent optical material 20 onto which lenses 6 are formed. The effect is the same as for the embodiments of Figures 4 and 5.

The invention having been described in the foregoing by reference to several embodiments, it is to be appreciated that the embodiments are in all respects exemplary and that modifications and variations thereto are possible without departure from the spirit and scope of the appended claims.

CLAIMS:

1. A process for producing an optically modified end to an optical fibre which comprises:
 - a. treating the end portion of the fibre in such a way as to allow the optical mode size to increase, and
 - b. forming a lens on the modified end portion
2. A process as claimed in claim 1, where the increase in mode size is accomplished by thermally diffusing the core of the fibre in the region close to the end.
3. A process as claimed in claim 2, where the core diffusion is carried out by laser.
4. A process as claimed in claim 3, where the laser used is a CO₂ laser.
5. A process as claimed in claim 1, where the increase in mode size is accomplished by splicing a section of substantially core-free fibre.
6. A process as claimed in claim 1, where the increase in mode size is accomplished by encapsulating the end of the fibre in optically transparent material.

7. A process as claimed in any of the preceding claims where the lens form is produced by laser machining.

8. A process as claimed in any of the preceding claims where the optically modified fibre end is designed to provide a substantially collimated laser beam in a given region.

9. A process substantially as herein described with reference to Figure 4 or 5 or 6 of the accompanying drawings.

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10. An optical fibre produced by a process as claimed in any of the preceding claims.

11. An optical fibre having an end portion such as to accommodate an increased mode size.

12. An optical fibre as claimed in claim 11 wherein a lens is formed on the end of said end portion.

13. An optical arrangement comprising first and second optical fibres as claimed in any of claims 10 to 12, the first optical fibre being arranged to emit a laser beam which is subsequently coupled back into the second optical fibre.

14. An optical arrangement as claimed in claim 13 including an optical isolator between the two optical fibres.

15. An optical arrangement as claimed in claim 14 wherein the optical
5 isolator is a Faraday rotator.

Amendments to the claims have been filed as follows

1. A process for producing an optically modified end to an optical fibre,
said process comprising:
treating an end portion of the fibre in such a way as to allow the
optical mode size to increase within the fibre, and
forming a lens on the end of the thus modified end portion of the fibre;
the fibre comprising a core and surrounding cladding and the increase
in mode size being accomplished by thermally diffusing the core of the fibre
in a region close to the end thereof so as to permit a light beam traversing the
fibre to expand before it encounters said lens.
2. A process as claimed in claim 1, where the core diffusion is carried
out by heating the fibre end portion with a laser.
3. A process as claimed in claim 2, where the laser is a CO₂ laser.
4. A process as claimed in any of the preceding claims where the lens
form is produced by laser machining.
5. A process as claimed in any of the preceding claims where the
optically modified fibre end is designed to provide a substantially collimated
laser beam in a given region.

6. An optical fibre comprising a central, doped core surrounded by cladding and wherein the core dopant is diffused at an end portion of the fibre so as to increase the optical mode size at the fibre end, a lens being formed on the fibre end.

5

7. An optical arrangement comprising first and second optical fibres as claimed in claim 6, the first optical fibre being arranged to emit a laser beam which is subsequently coupled back into the second optical fibre.

10 8. An optical arrangement as claimed in claim 7 including an optical isolator, a Faraday rotator for example, between the two optical fibres.



INVESTOR IN PEOPLE

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 Claims searched: 1-15

Examiner: Conal Clynych
 Date of search: 24 September 2001

Patents Act 1977 Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): G2J (JGEB, JGEAT)

Int Cl (Ed.7): G02B

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2089061 A (S T & C) see Figure 2	1 & 11 at least
X	EP 0575993 A2 (SUMITOMO) see Figure 7	11 at least
X	EP 0307487 A1 (MITSUBISHI) see Figure 4	1 & 11 at least
X	EP 0220439 A2 (A T & T) see Figures 3 & 11	1 & 11 at least
X	EP 0194842 A2 (SHILEY) see Figure 2	1 & 11 at least
X	US 5699464 A (LUCENT) see Figure 6	1 & 11 at least
X	US 4898450 A (P O C) see Figure 2	1 & 11 at least
X	US 4893890 A (LUTES) see Figure 1	1 & 11 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.